Saskatchewan
Environment
Mines Pollution
Control Branch

Radon Surveys in Saskatchewan

March, 1985

Saskatchewan

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Environment

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Control Branch

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RADON SURVEYS

IN

SASKATCHEWAN

PROGRESS REPORT

MARCH, 1985

INTRODUCTION

The Radiation Division of the Mines Pollution Control Branch of Saskatchewan Environment is responsible for the development of programs to ensure protection of the public from naturally occurring radiation hazards.

These hazards are generally associated with the presence of a radioactive gas, radon, in buildings. In the past, the province was involved in a joint program with the Federal Government regarding remedial measures in over one hundred homes in Uranium City. Initially, it was thought that the problems in Uranium City were caused by the use of waste rock from the Eldorado mine as fill around houses. However, detailed survey work indicated that the majority of problems were due to the presence of naturally occurring uranium in the ground. As the problem was naturally occurring, it would not necessarily be limited to areas with mineable uranium deposits. Uranium is to be found in minute amounts in soil throughout the province.

One of the first priorities of the Radiation Division was to conduct a survey program in communities of Saskatchewan to determine the location and magnitude of radon gas problem areas.

The opening phase of this program was a reconnaissance survey of the region North of the 55^{0} parallel. The results were published by the Saskatchewan Environment in the report, "Radon Monitoring in Northern Communities" dated June 1981.

This Progress Report incorporates those initial results as well as the results of the follow-up operations in the North and describes the reconnaissance surveys conducted in Southern Saskatchewan.

The next phase will be the continuous monitoring of homes that were identified by the Southern reconnaissance survey as possible locations of elevated radon levels throughout the year.

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THE PROBLEM

General

Radon is a naturally occurring radioactive gas that is formed during the decay of the uranium present in trace quantities in all common rocks, soils and in most building materials. The radioactive half-life of radon equals 3.82 days.

During radioactive decay radon gas forms a number of radioactive particulates, referred to as "radon daughters". It is these "radon daughters" in the breathing air that can present problems: inhaled they will attach to the lung tissues and cause damage to the cells through alpha radiation.

Measurements can be made for both radon and radon daughters. Radon concentrations are generally described in picocuries per litre (pCi/L). The unit used to describe radon daughter concentration is called a working level (WL).

Safety Criteria

The criterion used in Uranium City for cleanup of houses was 0.02 W.L. This criterion, applicable to all uranium mining communities in Canada, was established to ensure additional protection for those individuals working in the mines.

For areas other than uranium mining communities, the "Federal Provincial Subcommittee on Radiation Surveillance set the following interim guidelines:

- in homes where radon daughter concentration equals or exceeds 0.10 WL, a realistic estimate of the annual "effective dose-equivalent" must be determined.

- should this estimate exceed 0.5 rem/year, remedial measures shall be undertaken.

0.5 rem/year is the maximum permissible dose set out for general population by the Atomic Energy Control Regulations.

Special Considerations

As uranium transforms through radioactive decay into radon gas, a portion of this gas is ejected into the confining pore spaces of the host material at relatively high concentration, or partial pressure.

To relieve this partial pressure, radon gas may travel during its radioactive lifetime from several meters depth toward the surface in the process of diffusion.

Seeking easier routes of escape, it would naturally enter cracks and other openings and be carried by streams of soil gas to far greater distances, toward less confining spaces.

Excavations such as conventional basements present convenient relief from confinement and act as natural collecting places of radon generated all around in the neighboring materials and at essentially unpredictable distances.

Structures erected over basements tend to act as traps, preventing the ultimate escape of the gas into the open atmosphere. Depending on the airtightness of the structure, radon concentrations may build up to an undesireable magnitude.

According to the evidence collected by the survey, ventilation and natural leakage of conventional housing which now exist in the province tend to counteract to a satisfactory degree this process of radon build-up.

Problems may arise, however, with the emergence of airtight "energy efficient" housing designed for controlled ventilation at substantially reduced air change rates.

GENERAL OUTLINE OF THE SURVEY PROGRAM

Objectives

The survey program was launched in the summer of 1980 with the following objectives:

- to assess the existing radon levels in the non-uranium mining communities in the Province.

- to identify potential radon problem areas where control of construction techniques for new housing may be advisable.

Scope

Baseline studies of radon occurrence in major Canadian cities have been carried out by the Department of National Health and Welfare (Reference 3). Based on regional geology, there was good reason to assume that the most populated central part of the province would be within the range of the national average.

Since the purpose of the survey was to uncover above-average occurrences of radon, the two major target areas were defined as the Precambrian Region of the North (Figure 1) and coal-bearing Southern region of the Province (Figure 2).

Methodology

Indoor concentration of radon is known to vary considerably both with place and time in an essentially unpredictable manner. The task of detecting the highest occurrences over large areas within reasonable budget and time called for a process of successive eliminations through the following phases:

- Reconnaissance survey consisting of single measurements at a maximum number of locations, favouring the most likely places of high radon concentrations.

- Confirmation of high spot sample results by the use of time integrating monitoring devices.

- Intensive survey at confirmed problem locations with the aim to determine the maximum rates of exposure to radon daughters.

Each of these operations is described in greater detail in the following parts.

Reconnaissance Surveys

The first phase of the survey program was carried out in the summer months of 1980 and 1981, covering 16 communities in the Northern Region and 35 communities in the South. During these periods both the philosophy of the survey site selection and the procedure of measurements were kept identical.

The choice of survey locations was somewhat selective rather than completely random in order to minimize irrelevant fluctuations of the collected results (e.g. basements were given preference, heating and ventilation units were shut off and windows closed prior to survey). As a result, the samples are probably more "site specific" than they would be in case of truly random sampling.

The air sampling procedure was standardized to draw 72 litre air sample through a 0.8 μm glass fibre filter, to count and calculate the radon daughter concentration in Working Levels by the modified Kuznetz method. In addition, both the average and maximum gamma radiation levels were measured at each location using an "EDA Threshold Gamma Ray Spectrometer" (GRS 400) which was cross-calibrated against the scintillometer employed in the Uranium City cleanup operations at the time.

Results of these reconnaissance surveys are presented separately in the following chapters.

Follow-Up Monitoring

The concentration of radon and radon daughters in the atmosphere of homes is subject to both short-term and seasonal time variations over considerable range and in an essentially unpredictable manner. Single air samples taken in a community at any given time would therefore be of little value for estimating average yearly exposures, but most valuable in pointing out suspected problem locations. Such suspected cases could be then followed up by continuous radon monitoring over an extended period, in order to arrive at the yearly average radon concentrations.

Following the northern reconnaissance survey it was decided to use passive monitoring devices, called "track etch" detectors during the first 6 months of 1981. The procedure and results of this operation are described in Chapter "Follow-Up Monitoring in Northern Saskatchewan".

Detail Surveys

High year-round radon daughter concentration detected in a basement may indicate not only possible radon pollution of the

living areas in that house, but in other homes of the general neighbourhood as well. The final phase of the survey consists of detail investigation of confirmed high radon occurrances in order to identify all related problem locations and ultimately, to evaluate the year-round radon daughter concentration at the most occupied parts of such locations.

The survey of Northern Saskatchewan that is now considered complete identified one target area for such detail investigation (Chapter: Detail Survey).

RECONNAISSANCE SURVEY OF NORTHERN SASKATCHEWAN

Survey Area

The survey area is broadly defined as the part of Saskatchewan that extends north of the 54° parallel. Exact delineation of the area is shown on the "Preliminary Index Map" (Figure 1).

Geology

Geologically the entire survey area is part of the Precambrian Shield, where one could expect somewhat higher than average uranium concentrations and greater than normal frequency of radon accumulations. Beyond that, geological literature of the region offers little information in the present context.

Survey Coverage

The 16 non-mining communities covered by the survey were selected with the intent to obtain a fair representation of all existing population centers of the region from view of geographical location, ethnological character and geological setting.

In total, 313 samples were taken which, according to the 1979 tabulation of DNS Municipal Service Branch, corresponds to more than 10% survey coverage of all homes and about 50% coverage of all houses with basements in the 16 communities visited. In terms of all Northern communities (excluding Uranium City) this would correspond to more than 4% coverage of all houses and to more than 20% of those with basements.

Results

The gamma radiation survey recorded largely insignificant variations in the 5-25 μR/hr range.

The results of radon daughter sampling are summarized in Table 1, showing the distribution as well as the Arithmetic and Geometric Mean of the radon daughter levels for each community. The Geometric Mean, derived from the logarithm of the individual entries, is particularly relevant for the type of random distribution that the radon sources represent in nature.

Assessment of Radon Hazards

The question of potential radon hazards could be of concern to residents of this area, which contains some of the world's most

spectacular uranium deposits. Even though the survey was designed to accentuate potential hazards the results did produce factual and reassuring answers. In summary:

- none of the homes surveyed would require "prompt interim remedial action" by rather stringent A.E.C.B. criteria which applied to uranium mining communities (Reference 2).

- only 5 of the homes surveyed, or 1.6% of the total, would require follow-up investigation according to Guidelines of Federal Provincial Subcommittee of Radiation Surveillance which apply to non-uranium mining communities (Reference 1).

At the time of the survey these guidelines did not exist, however, and the scope of the follow-up monitoring was planned on basis of AECB criteria (Reference 2) to include all locations above the 0.01 W.L. limit (Chapter: "Follow-Up Monitoring").

Identification of Radon Problem Areas

In order to reach the second objective of the survey it was decided to take advantage of the geophysical information generated by the Geological Survey of Canada in a program designed to aid uranium exploration. As a result comprehensive airborn gamma ray spectrometric survey coverage exists over the greater part of Northern Saskatchewan.

The most valuable part of the survey results at least from the present point of interest, are the counts recorded on the "uranium channel" which, after due corrections, processing and conversions are presented in the form of "equivalent uranium" (eU) contour maps showing the interpreted near-surface concentration of uranium in terms of parts per million (p.p.m.).

The rationale for using such "eU" maps for identifying radon problem areas is given in the following points:

- The "uranium channel" of such airborn surveys is designed to admit only the characteristic gamma rays emitted by radionuclide Bismuth 214, and reject those from other natural sources. In a most direct sense the survey therefore measures only the distribution of that one radionuclide near the top surface.

- Bismuth 214 is generated in nature by the radioactive decay of Uranium 238 in a process that requires millions of years. Its local concentration may therefore be indicative of uranium deposits and interpreted in terms of "equivalent uranium" (eU).

- Radon 222 is also part of the same decay process, however. In fact, Bismuth 214 represents one of the four "radon daughters" measured by indoor air sampling and these are only hours apart in the decay process.

It seemed logical to expect that if "eU" contour maps proved to be valuable tools in the discovery of uranium deposits, they would provide more direct and dependable basis for identifying broad areas of relatively high radon occurrence.

To test this idea in light of the collected field results, it was decided to use the 1.00 ppm "eU" contour as the cutoff marking "potential radon problem areas" and to compare the survey results obtained on either side of this boundary.

Correlation of the average radon daughter concentration and WL distribution, obtained by the ground surveys in areas corresponding to lower than 1 ppm eU airborne results with the Provincial background, determined by the National Surveys in the central regions, shows that the two are near identical (Table 3). Therefore, designation of such zones as "areas of normal radon occurrence" appears justified.

On the other hand, inspection of the ground survey results in Table 3, obtained in areas corresponding to higher than 1.0 ppm airborne measurements, clearly supports designation of those zones as "potential radon problem areas".

The foregoing conclusions provided the basis for the development of a "Preliminary Index Map" showing the potential radon hazard areas in Northern Saskatchewan (Figure 1).

This map is a new concept and open to critical review. In addition, the field evidence that supports its present form is limited and modifications may result from more extensive field information. It should be also borne in mind that the map is based on reconnaissance air coverage with flight lines 5 km apart, consequently it does not contain all detail. For specific information the Mines Pollution Control Branch of Saskatchewan Environment should be consulted.

TABLE 1 - RADON DAUGHTER CONCENTRATIONS IN WORKING LEVELS (WL)

COMMUNITY	NO. OF SAMPLES	0.00-0.01	0.01-0.02	0.02-0.05	0.05-0.10	ABOVE 0.10	ARITHMETIC MEAN	GEOMETRIC MEAN
CAMSELL PORTAGE	23	16	4	2	1	0	0.0183	0.0098
STONY RAPIDS	35	13	5	8	6	3	0.0373	0.0185
WOLLASTON LAKE	18	18	0	0	0	0	0.0014	0.0010
KINOOSAO	6	4	2	0	0	0	0.0078	0.0053
LA LOCHE	33	31	2	0	0	0	0.0040	0.0025
PELICAN NARROWS	10	8	1	1	0	0	0.0064	0.0033
BRABANT LAKE	7	5	1	1	0	0	0.0151	0.0124
MISSINIPPE	4	1	2	1	0	0	0.0223	0.0201
STANLEY MISSION	16	7	1	3	4	1	0.0451	0.0207
SANDY BAY	20	13	4	3	0	0	0.0100	0.0056
SOUTHEND	12	10	2	0	0	0	0.0072	0.0021
CREIGHTON	52	40	7	5	0	0	0.0065	0.0029
LA RONGE	44	31	1	5	6	1	0.0137	0.0046
DESCHAMBAULT	5	5	0	0	0	0	0.0080	0.0067
PINEHOUSE LAKE	12	2	3	5	2	0	0.0274	0.0196
DENARE BEACH	16	6	4	5	1	0	0.0140	0.0096
	313	210	39	39	20	5	0.0151	0.0047

RECONNAISSANCE SURVEY OF SOUTHERN SASKATCHEWAN

Survey Area

The survey included major population centers in the general region of the Ravenscrag Formation, from the Alberta border to Estevan.

The western side of this area is partly covered by airborne gamma ray spectrometer survey conducted by the Geological Survey of Canada in 1976 (Figure 2).

Geology

The predominant geological feature of the survey area is the Ravenscrag Formation of the Cenozoic Period, consisting of about 300 m of fine to medium grained, locally cemented clastics, interbedded with lignite coal seams of varying thickness. It is known that as a general rule the top lignite beds contain uranium.

Outcropping of this formation mainly occurs over relatively small areas: between ranges 10-W2 and 7-W3; north to Township 5 and in the deeply cut valleys of Frenchman River and Big Muddy. As for the rest, the Ravenscrag Formation is overlain by up to 50 m of glacial drift; by younger formations (Cypress Hills & Wood Mountain Formation) or both.

Survey Coverage

A total of 613 samples were collected from as many houses in 35 communities (Figure 2).

Based on "1981 Municipal Directory" the survey covered more than 10% of the existing dwellings.

Reflecting on the predominant nature of structures in this area, all readings were taken in basements.

Results

Measurements of gamma radiation failed to detect significant anomalies. All readings were below 30 uR/h.

The results of air sampling are shown in Table 2 and discussed in the chapters that follow.

Assessment of Radon Hazards

The overall indication of the survey is that radon does occur in Southern Saskatchewan with unexpected frequency and concentration.

The relatively high uranium content of soil and bedrocks only partially accounts for the fact that the average indoor concentration of radon in the Southern survey area is about twice as high as was observed in the North (Geometric means: 0.0097 v. 0.0055 WL). The difference between the predominant building structures of the two regions is probably a strong contributing factor. For example, in the South all homes visited had basements with concrete floors. By contrast only about 2/3 of the Northern homes had basements.

Though single air sample readings represent only one observation of a widely fluctuating quantity, the results allow the following interim assessment of radon hazards:

- There were no cases encountered that would require "prompt interim remedial action" by AECB's clean-up criterion (0.15 WL, Reference 2).

- 10 homes, or as in the North, 1.6% of all survey locations require follow-up investigation according to the Guidelines of Reference 1.

Identification of Radon Problem Area

The task of delineating the potential radon problem areas from the Southern survey results was not assisted by related information from other sources. Geological maps did provide comprehensive and detail outline of the Ravenscrag Formation which is believed to contain the source of elevated radon levels but, due to extensive displacements by erosion and masking of these sources by overburden, correlation between geological data and survey results proved to be erratic.

Relying entirely on the survey results, the potential radon problem area may be defined as one extending from the Western border of the survey area to a parallel N-S boundary placed between Minton and Gladmar. With the notable exception of the towns Shaunavon, Pambrun and Piapot, radon daughter concentration in this relatively sparsely populated area is consistently high, averaging 0.0136 WL. In contrast, the average radon daughter concentration in the rest of the survey area is 0.0041 WL, which is well in line with the provincial background established by the National Survey.

The scope of the survey was not sufficient to identify the boundaries of this potential radon problem area toward the South or toward the more densely populated regions of the North.

TABLE 2

RADON DAUGHTER CONCENTRATIONS IN WORKING LEVELS (WL)

COMMUNITY	NO. OF SAMPLES	0.00 to 0.01	0.01 to 0.02	0.02 to 0.05	0.05 to 0.10	ABOVE 0.10	ARITHMETIC MEAN	GEOMETRIC MEAN
CORONACH	49	7	9	24	6	3	0.034	0.024
WILLOW BUNCH	30	11	5	11	3	0	0.024	0.016
ROCKGLEN	30	12	6	9	3	0	0.021	0.011
SCOUT LAKE	5	5	0	0	0	0	0.003	0.002
ST. VICTOR	4	0	2	1	1	0	0.036	0.031
FIFE LAKE	4	0	2	2	0	0	0.021	0.019
LISIEUX	6	1	3	1	0	1	0.032	0.020
WOOD MOUNTAIN	5	1	2	0	2	0	0.043	0.021
FIR MOUNTAIN	3	1	0	0	1	1	0.067	0.040
GLENTWORTH	9	5	2	1	1	0	0.018	0.011
McCORD	7	4	0	3	0	0	0.012	0.009
FERLAND	11	0	3	4	4	0	0.041	0.033
MANKOTA	25	5	11	7	2	0	0.019	0.015
KILLDEER	4	0	1	0	1	2	0.113	0.080
LAKE ALMA	10	6	3	1	0	0	0.010	0.007

Table 2

RADON DAUGHTER CONCENTRATIONS IN WORKING LEVELS (WL)

COMMUNITY	NO. OF SAMPLES	0.00 to 0.01	0.01 to 0.02	0.02 to 0.05	0.05 to 0.10	ABOVE 0.10	ARITHMETIC MEAN	GEOMETRIC MEAN
GLADMAR	5	3	2	0	0	0	0.008	0.008
MINTON	10	4	2	4	0	0	0.016	0.012
BIG BEAVER	5	2	2	0	1	0	0.018	0.012
KINCAID	15	6	7	2	0	0	0.012	0.009
ANEROID	10	5	2	3	0	0	0.013	0.008
HAZENMORE	9	4	5	0	0	0	0.012	0.011
PONTEIX	30	12	11	7	0	0	0.013	0.009
CADILLAC	10	2	4	2	2	0	0.022	0.016
SHAUNAVON	60	47	11	2	0	0	0.006	0.004
ADMIRAL	6	1	3	0	1	1	0.039	0.021
DOLLARD	6	3	2	1	0	0	0.011	0.009
EASTEND	30	9	7	9	4	1	0.028	0.018
PAMBRUN	10	8	2	0	0	0	0.006	0.004
HODGEVILLE	20	9	6	5	0	0	0.013	0.011
VANEGUARD	20	8	7	4	0	1	0.018	0.011
PIAPOT	6	4	2	0	0	0	0.006	0.003

Table 2

RADON DAUGHTER CONCENTRATIONS IN WORKING LEVELS (WL)

COMMUNITY	NO. OF SAMPLES	0.00 to 0.01	0.01 to 0.02	0.02 to 0.05	0.05 to 0.10	ABOVE 0.10	ARITHMETIC MEAN	GEOMETRIC MEAN
TOMPKINS	10	3	5	2	0	0	0.015	0.012
GULL LAKE	25	15	8	2	0	0	0.010	0.008
MAPLE CREEK	67	40	15	10	2	0	0.012	0.007
ESTEVAN	58	41	14	2	1	0	0.009	0.005
TOTAL	613	283	166	119	35	10	0.0179	0.0097

TABLE 3

REGIONAL DISTRIBUTION OF RADON OCCURRENCE IN SASKATCHEWAN

REGIONS	SAMPLE NO.	BELOW 0.010 WL	0.011 to 0.020	0.021 to 0.050	0.050 to 0.100	ABOVE 0.100 WL	GEOMETRIC MEAN of WL	GEOMETRIC STANDARD DEVIATION
Central-Total[1]	1730	79%	14%	6%	0.9%	0.1%	0.0039	3.1
Regina	961	75%	15%	8%	1.7%	0.3%	0.0044	2.9
Saskatoon	769	84%	12%	4%	0.0%	0.0%	0.0034	2.5
North-Total[2]	229	70%	14%	10%	3.7%	2.2%	0.0049	3.3
Areas of Normal Radon Occurrence (below 1 ppm eU)	155	85%	9%	5%	0.0%	1.6%	0.0031	3.1
Potential Radon Problem Areas (above 1 ppm eU)	74%	29%	23%	21%	11.8%	6.7%	0.0128	3.9
South-Total[2]	613	46%	27%	20%	5.7%	1.6%	0.0097	3.1

(1) Survey performed by the Radiation Protection Bureau, National Health & Welfare

(2) Only survey results from basements considered.

FOLLOW-UP MONITORING IN NORTHERN SASKATCHEWAN

Scope

The distribution of continuous alpha monitoring devices was based on the only existing safety criteria of 1981 (Reference 2) as follows:

- All houses registering 0.01 W.L. or higher radon daughter concentration were provided with one monitor placed near the air sampling location.

- Houses exceeding 0.05 W.L. were provided with one additional monitor placed at the point of highest occupancy.

- Finally, monitors were placed in several randomly selected homes registering less than 0.01 W.L. in order to confirm preliminary indication of the low level.

The monitoring period was scheduled to last from mid-winter to mid-summer of 1981 in order to evenly represent the seasonal peaks and transitions of the entire year.

Method

The program called for a device capable of measuring the cumulative alpha radiation unattended over extended time periods, with meaningful accuracy and at affordable costs. "Track Etch" detectors alone seemed to meet all these requirements.

The essential part of the detector is a small sensor "chip" made of a polyester material that undergoes permanent surface damage on impact by alpha particles. At the end of the monitoring all such "tracks" left behind on the chips' surface are made visible by "etching" in order to be counted. Knowing the time of exposure, from the density of tracks the average alpha activity, or the average air concentration of alpha emitters may be derived. The sensor is oblivious to all forms of radiation other than alpha.

Options and Costs

Two types of detectors and data processing services were commercially available in 1980: one where the sensor chip was mounted on a card and freely exposed to radon and daughters; the other where the sensor was mounted on the inside bottom of a filtered cup and for all practical purposes exposed only to radon. The results obtained from either were expressed in terms of average radon concentration, pCi/L.

In choosing between the two available options naturally the more advanced and selective "cup" model was favoured until overriding practical considerations decided the issue in favour of cards. Field testing of the two models side by side in a small community quickly showed that however hidden, few of the cups would survive children's curiousity while the card can be placed unobtrusively to avoid tampering.

The cost did not depend on the choice or on the length of use of monitoring period, it depended solely on the "sensitivity level" required at the data processing stage. Opting for the middle (1.0 pCi/L-month) determined the basic costs of the survey as $40 (U.S.)/location.

Terminology

To reconcile the terminology of the monitoring results (pCi/L) with the more relevant units of the reconnaissance survey (W.L.) requires knowledge of the radioactive equilibrium factor ("f") applicable to radon and radon daughters during the monitoring period.

As the magnitude of "f" may vary both with time and locations anywhere between 0.3 - 0.7, any assumed value applied to short-term measurements is bound to introduce considerable errors.

Research commissioned by the Atomic Energy Control Board in the Bancroft Area (Reference 5) showed, however, that the main parameters of these variations are of recurrent cyclic nature which even out at a constant yearly average "f" value. In Bancroft this average "f" was observed as 0.47.

In order to convert the yearly average "pCi/L" radon concentrations obtained through continuous monitoring into average WL, with assuredly small errors on the side of caution, an average "f" of 0.50 has been assumed.

Results

The average yearly radon daughter concentration values (Col. 1) at 61 suspect or control locations are listed in comparison with the original grab sample readings in Table 4.

The results conclusively show that outside of La Ronge none of the homes surveyed in Northern Saskatchewan required further investigation, as set out by the applicable criteria. (Reference 1). Considering that all suspected problem locations were in basements, of which about 50% were covered by the survey, the likelihood that significant radon problems may exist undetected in the surveyed communities seems remote. New "energy efficient" housing may basically change this assessment.

One further indication of the results is that the average radon daughter concentrations is consistently lower than grab sample readings which means that the reconnaissance survey was carried out near the crest of the seasonal W.L. variations. As shown by the 4th column of Table 4, the extent of this over-estimation does vary, but the overall reduction of the original survey results by a factor of 0.67 would bring them closer to reality. It should be noted that this correction factor does not necessarily apply outside of Northern Saskatchewan.

TABLE 4

CORRELATION OF MONITORING AND GRAB SAMPLING RESULTS

LOCATION & (Sample No.)	(1) $\overline{WL}$ (av)	(2) WL (grab s.)	GEOMETRIC MEAN OF RATIOS (1)/(2)	GEOMETRIC STANDARD DEVIATION
DENARE BEACH (10)	0.003	0.013		
	0.005	0.009		
	0.013	0.071		
	0.004	0.010		
	0.007	0.043		
	0.009	0.010		
	0.007	0.010		
	0.009	0.016		
	0.009	0.042		
	0.010	0.035	0.036	1.83
PINEHOUSE LAKE (9)	0.003	0.030		
	0.010	0.033		
	0.011	0.016		
	0.022	0.057		
	0.012	0.023		
	0.013	0.016		
	0.017	0.033		
	0.033	0.048		
	0.006	0.011	0.44	1.89
PELICAN NARROWS (4)	0.006	0.021		
	0.007	0.006		
	0.008	0.009		
	0.041	0.013	0.96	4.26
LA LOCHE (3)	0.004	0.012		
	0.006	0.008		
	0.003	0.005	0.53	1.52
STONY RAPIDS (14)	0.003	0.001		
	0.002	0.001		
	0.017	0.013		
	0.003	0.010		
	0.043	0.024		
	0.019	0.007		
	0.028	0.090		
	0.033	0.068		
	0.006	0.020		
	0.015	0.020		
	0.006	0.023		
	0.045	0.135		
	0.062	0.039		
	0.015	0.011	0.83	2.48

TABLE 4 (con't)

CORRELATION OF MONITORING AND GRAB SAMPLING RESULTS

LOCATION & (Sample No.)	(1) $\overline{WL}$ (av)	(2) WL (grab. s.)	GEOMETRIC MEAN OF RATIOS (1)/(2)	GEOMETRIC STANDARD DEVIATION
LA RONGE (8)	0.037	0.082		
	0.100	0.064		
	0.026	0.079		
	0.030	0.058		
	0.045	0.112		
	0.047	0.057		
	0.029	0.022		
	0.037	0.022	0.74	1.92
STANLEY MISSION (12)	0.030	0.038		
	0.090	0.063		
	0.011	0.023		
	0.010	0.002		
	0.014	0.005		
	0.030	0.113		
	0.020	0.076		
	0.021	0.075		
	0.020	0.038		
	0.011	0.067		
	0.003	0.024		
	0.008	0.008	0.58	3.10
CREIGHTON (9)	0.021	0.019		
	0.022	0.019		
	0.008	0.022		
	0.026	0.021		
	0.008	0.010		
	0.016	0.012		
	0.007	0.012		
	0.018	0.025		
	0.018	0.013	0.89	1.57
OVERALL AVERAGE FROM 61 LOCATIONS:			0.67	1.59

DETAIL SURVEY

Background

Review of air sampling results during the reconnaissance survey of La Ronge showed consistently low WL's across the village except for 8 incongruously high readings obtained from homes in the same general location. Continued spot-sampling of the neighbouring homes and the 1981 track-etch monitoring results (Table 4) both confirmed anomalous radon daughter concentration in the neighbourhood and the need of detail investigation.

Sequence and Results of Investigation

Toward the end of the 1981 field season air sampling was conducted in 49 homes with the normal procedure in order to define the extent of anomalous zone. As a result, the problem area is now limited to 4 suburban city blocks (approximately 0.05 square km) containing 59 relatively new housing units of above average quality. With one exception, all have basements with living areas. Only 8 of these homes were privately owned.

During the first 6 months of 1982 track-etch monitoring was carried out in 42 of the 58 basements using the card-mounted detectors described earlier. The detectors were mounted at the points of highest expected radon concentration that were not necessarily inhabited. The results identified 7 basements as potentially unsuited for normal occupancy. As temporary precaution the owners of these homes were advised not to use their basements as sleeping accommodations.

The purpose in the concluding phase of the survey was to evaluate the existing maximum exposure rates to radon daughters in all 59 homes by monitoring the year-around concentrations at the place of highest occupancy of both levels. As by the end of 1982 a new track-etch model became available that combines the ruggedness of the existing card-mounted version with the higher accuracy of the cup-type, this model was used in this final phase lasting from January to July 1983.

The results confirmed that while the WL's in most homes were higher than average, the existing criteria were not exceeded in any of them in the living areas above ground level. In the inhabited parts of the basements 2 of the previously identified 7 were singled out for limited occupancy or, depending on the owner's choice, for remedial measures.

Tenants and owners of these 59 homes were both notified about the final results of the investigation.

DISCUSSION

(1) Environmental radon as a potential health hazard is a relatively new concept. The radioactive inert gas Radon 222 was discovered as part of the Uranium 238 decay chain around the turn of the century, and only in the late fourties were its decay products identified as a health hazard closely associated with uranium mining activities and communities. Investigations by Swedish scientists Sievert and Hultginst during 1953-56 brought to light that exposure to radon decay products could lead to high lung doses also in poorly ventillated homes away from uranium mining areas. This set off world-wide, multi-phase scientific studies. As a result the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) was in the position to conclude in its 1982 Report to the U.N. General Assembly that about one-half of the annual dose from natural sources of radiation is now calculated to be due to the presence of radon in the air inside of buildings. (Reference 9).

(2) The above statement establishes the universal significance of the problem. Being an estimated average however, it naturally comprises a variety of significance levels, ranging from relatively low to unacceptably high exposures depending on the location. To single out and remedy the critical problem locations constitutes the most pressing and yet the least pursued objective of the ongoing efforts to come to grips with the problem of indoor radon pollution.

The reason for this is provided indirectly by a paper presented at the "International Seminar of Indoor Exposure to Natural Radiation and Related Risk Assessment", of 1983 (Reference 10) on the Swedish radon control program. The direct cost of the survey carried out since 1979 is reported at $3 million (US). On the basis of the results, it is estimated that in about 40,000 Swedish homes the radon concentration exceeds the remedial action criterion for existing buildings, which is more permissive than it is in Canada. The unit cost of remedial work to the owners would be in the range of $100 - $6000. The state provides favourable loans for remedial actions to the affected home owners but ultimately the cost of radon control program to the public will be predictably high.

(3) In 1980, the Government of Saskatchewan decided to carry out environmental radon surveys through the Mines Pollution Control Branch of the Department of Environment, starting with the northern part of the province.

It is estimated that 15-20% of all homes with basements of the region were sampled, 61 suspect homes were continuously monitored and in the only area of concern located in La Ronge, 59 homes were subjected to intense investigation. Using the more stringent Canadian criteria, none of the living areas above ground level and only two basements were identified as undesireable for continuous occupation.

Considering the relatively high radon daughter concentrations encountered by the reconnaissance survey in the South Western part of the Province, it should be remembered that the survey was conducted during the same part of the year, following the same procedure as it was in the North. The construction and heating system of the homes with basements that were visited in the two regions were not significantly different. Consequently it is reasonable to expect the same mitigating factors at work in the South that were experienced in the North while determining the year-round average concentrations. Continuous monitoring of the 10 homes presently designated for follow-up action would certainly eliminate some, possibly most from the list.

The combined results of the provincial surveys and those obtained by the Radiation Protection Bureau in Regina and Saskatoon conclusively show that the problem of indoor radon pollution of presently existing housing in Saskatchewan is much different than the Swedish situation.

(4) Differentiation between "areas of normal radon occurrence" and the "potential radon problem areas" becomes significant in connection with the new generation of energy efficient homes designed for controlled ventilation at reduced rates.

Analytical and experimental studies (References 7 and 8) concur about the disproportionate increase of radon daughter concentration with decreasing ventilation rates. Combining these studies with the statistical analysis of all radon surveys carried out in Saskatchewan leads to Figure 3 showing varying frequency of follow-up cases, i.e. those exceeding 0.10 WL, at various ventilation rates in different parts of the Province. The year-round average air leakage rates of the presently conventional homes has never been established, but based on a concensus of expert opinions, an overall representative value of 1.0 air change per hour (ACH) is assumed.

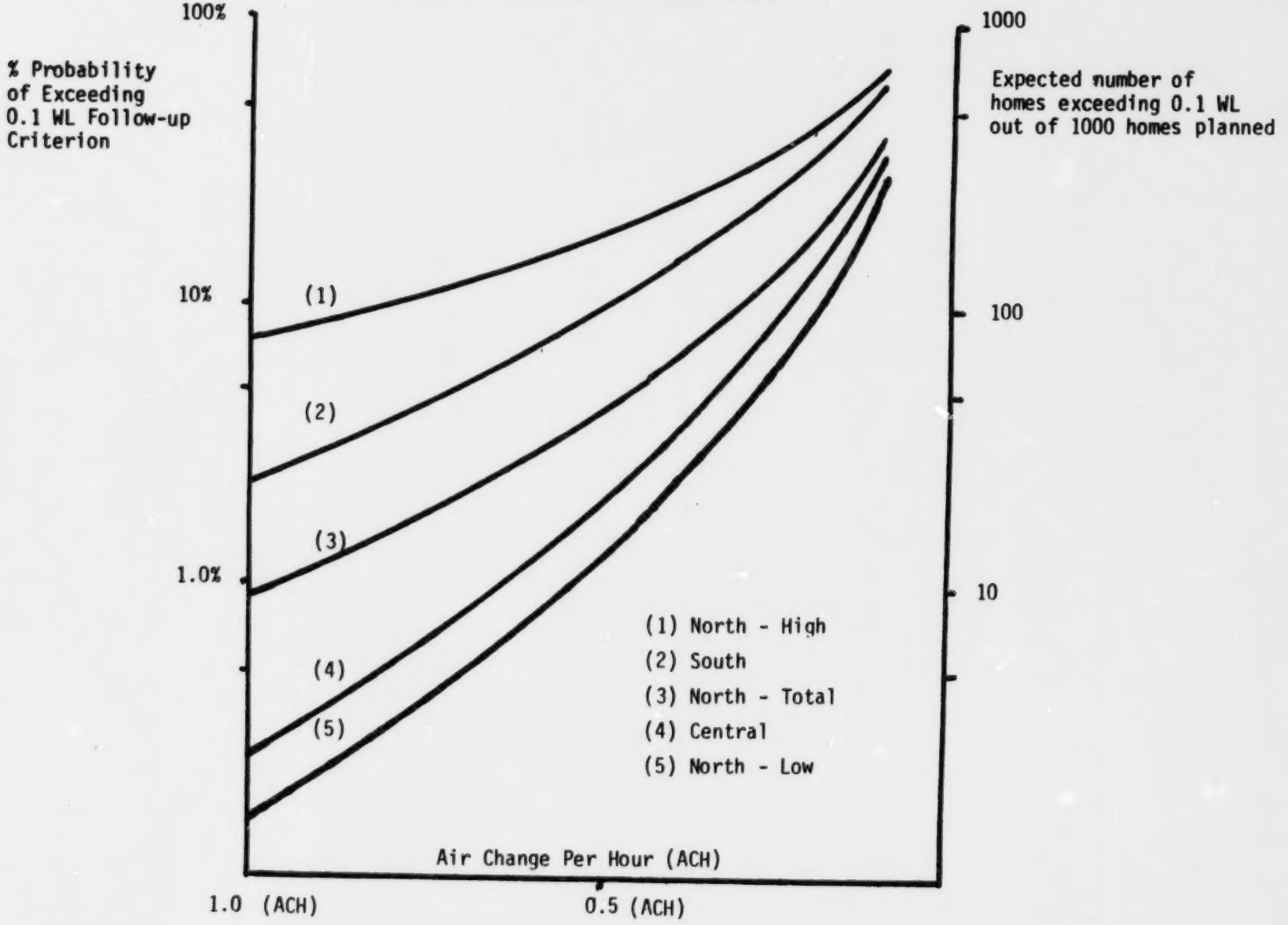
The significance of the "Preliminary Index Map" derived in the Northern survey is clearly demonstrated in Figure 3: by subdividing the Northern Region into "Low" and "High" zones, corresponding to the white "Areas of Normal Radon Occurrences" and the shaded "Potential Radon Problem Areas" of the "Preliminary Index Map" (Figure 1), we find that the average radon daughter concentration level in "Low"

parts, comprising about 80% of the total area, is actually lower than the background level of the Central Region. Therefore, the radon problems commonly associated with the North are largely confined to the relatively limited shaded areas shown in the Map. As a practical example, we learn from Figure 3 that if energy efficient houses designed for 0.5 ACH were built in the North, only about 1 out of 100 would require follow-up monitoring in the "Low" zones, while in the shaded "High" risk zones of the Map the ratio would be 1 out of every 5.

When the survey program started in 1980, energy efficient housing existed only in the form of pilot projects. By 1982, according to the Energy Mines and Resources Canada figures, 52% of all the new homes sold in the Province were of the energy efficient type. The trend is irreversible and it is accelerated by government support. In 1983 the Federal "Super Energy Efficient" program came into effect educating builders and building up to 27 demonstration units across Saskatchewan. Radon proofing of these homes is not part of the Federal program. The findings contained in this report must be considered in the administration of energy efficient housing programs.

FIGURE 3

REGIONAL % PROBABILITY OF EXCEEDING 0.10 WL FOLLOW-UP CRITERION AS FUNCTION OF DESIGN AIR CHANGE RATES



NOTE: The average air change rate of conventional homes is assumed to be 1.0 ACH

Saskatchewan Enviroment (figure 2)

Mines Pollution Control Branch

RADON SURVEY
of Southern Saskatchewan

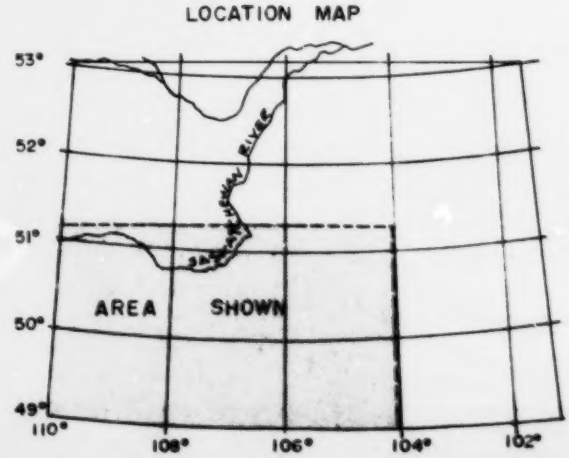
LEGEND

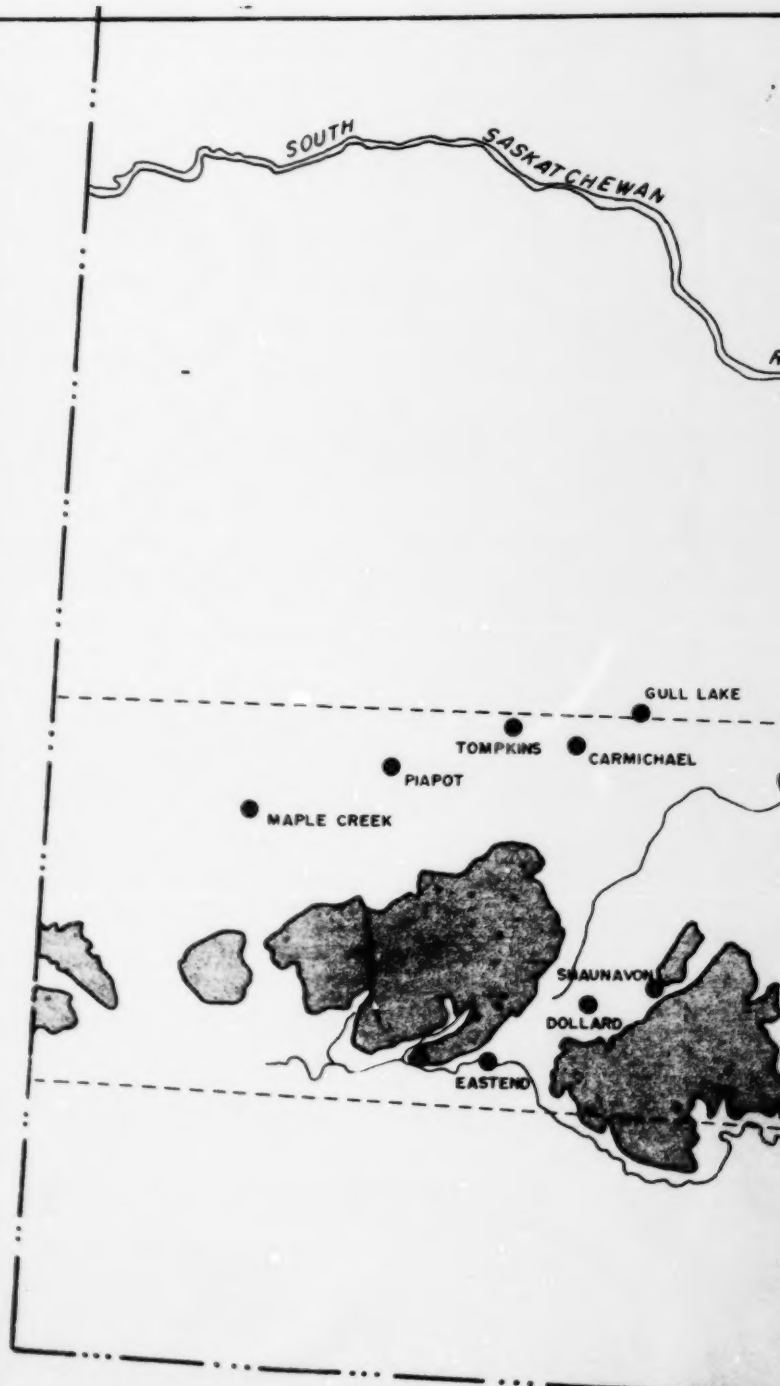
- EXTENT OF THE TERTIARY RAVENSCAG FORMATION
- AREA COVERED BY G.S.C AIRBORNE GAMMA SPECTROMETER SURVEY
- COMMUNITIES SURVEYED

SCALE: 1:1,000,000

MAP COMPILED BY B. BUSCH

LOCATION MAP





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(figure 2)

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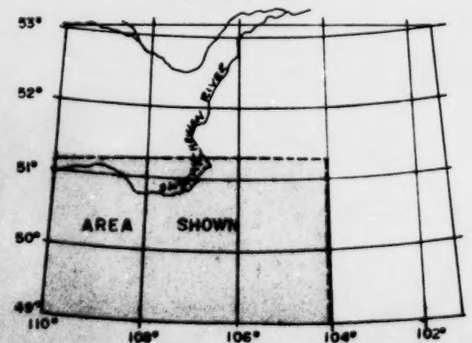

SOUTH SASKATCHEWAN RIVER

SWIFT CURRENT CREEK

GULL LAKE

TOMPKINS

CARMICHAEL

PIAPOT

MAPLE CREEK

HODGEVILLE

OLD WIVES LAKE

PAMBRUN

VANGUARD

LAKE OF THE RIVERS

ADMIRAL

CADILLAC

PONTEIX

ANEROID

HAZENMORE

KINCAID

SHAUNAVON

DOLLARD

EASTEND

PINTO CREEK

WOOD RIVER

FERLAND

MANKOTA

McCORD

GLENTWORTH

FIR MOUNTAIN

WILLOWBUNCH LAKE

FRENCHMAN RIVER

EASTERN BOUNDARY OF POTENTIAL RADON PROBLEM AREA

U.S.A.

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(4) E.G. Letourneau, D.T. Wigle "Mortality and Indoor Radon Daughter Concentrations in 13 Canadian Cities". Radiation Protection Bureau, Bureau of Epidemiology, Department of National Health and Welfare, Ottawa, Canada.

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(8) Cliff K.D.: Assessment of Airborne Radon Daughter Concentrations in Dwelling of Great Britain. Phys. Med. Biol. 1978 Vol. 23 No. 4 pp. 696-711.

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MAPS NOT

FILMED

CARTES

OMISES